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Effect of ammonium nitrate and urea fertilizers on nitrogen mineralization, especially nitrification, in a forest soil.

Inverkan av ammoniumnitrat och urea
på kvävemineraliseringen,
särskilt nitratbildningen i skogsmark.

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ABSTRACT

Incubation experiments of up to nine weeks were carried out with humus and mineral soil samples from ammonium-nitrate and urea fertilized plots. Special attention was devoted to nitrification. High amounts of nitrate occurred in the humus from fertilized plots with the two higher urea levels.

Very little nitrate was found in the humus from most ammonium-nitrate fertilized plots (one of the five plots with the highest N-level showed notable nitrification after incubation).

The CO_2-release from humus samples was measured during incubation, and there was a tendency to a negative effect of fertilizers, at least at higher levels.

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INTRODUCTION

Nitrogen fertilizers are used in Swedish forests. The average application rate in 1976 was 143 kg N per hectare (Holmen, 1977). The percentage ratio of nitrogen fertilizers (calculated as N) in 1976 was urea/ammonium nitrate, 10:90, compared with 38:62 in 1974.

The Department of Forest Ecology conducts a serie of optimum nutrition experiments in young forest stands. A comparison of ammonium nitrate and urea application is included in one experiment, No E55 Norrliden, located 100 km NW of Umeå (Holmen and al. 1976). Samples were collected from this experiment for study of ammonification and nitrification in soil samples from fertilized and non-fertilized plots. We were especially interested to follow possible occurrence of nitrification on the plots treated by nitrogen fertilizers.

Soil samples from some plots fertilized with nitrogen at Hökaberg (Tamm & Popović, 1974) showed nitrate formation after six and nine weeks' incubation. Heilman (1974) found nitrate formation in soil samples treated by urea in the laboratory from Douglas fir and Western Hemlock sites in western Washington.

Nitrate formation after urea treatment was recorded in lysimeter experiments in Norway (Overrein, 1971, 1972). These results are at variance with those reported by Nakos (1976) who found no nitrification after urea treatment in Greece. But Robert and Knowles (1966) observed some nitrate formation in humus after urea treatment in the laboratory. No nitrate production after urea addition to humus in laboratory and following incubation was reported by Weetman, Knowles and Hill (1972).

METHODS AND MATERIALS

Soil samples for the incubation experiment were collected September, 9-12, 1975 from all plots within the nitrogen dosage experiment E55 Norrliden in North Sweden. The fertilizers were ammonium nitrate or urea added annually at three different levels from the start in 1971. The last fertilization was carried out in the beginning of June 1975. The following quantities in total were applied (for the period 1971-75):

N1 = 260 kg N per hectare
N2 = 520 kg N " "
N3 = 780 kg N " "
P2 = 80 kg P " "
K2 = 152 kg K " "

Sampling of humus and mineral soil (0-5 cm) was conducted in mathematical spacing on each plot by an auger (area 38.48 cm^2), 18 individual samples. As in earlier experiments the fresh material was sieved through a 3 mm screen and incubated, after adjustment of moisture content to about 60 % WHC (Popović, 1971). The flasks were supplied with polyethylene film to prevent water loss and no additional water was added during the incubation. The temperature was constant at 20°C. Part of the experimental material (from 24 plots) was put into special incubation flasks for measuring the CO_2-evolution during the experiment period according Nömmik (1971). The incubation periods were six and nine weeks.

For determination of ammonia and nitrate nitrogen, an extract was prepared by shaking 40 g of fresh soil in 200 ml of 1 % $K\,Al\,(SO_4)_2$ solution. The ammonia nitrogen was coloured by indophenol reagens and the blue colour produced was measured on the autoanalyser (Technicon, Selmer-Olsen, 1971). The nitrate was reducted with cadmium-amalgam to nitrite, which was diazorised with sulphanilamide and the product coupled with N1-naphtyethylendiamine to form a highly coloured azo dye, which was measured at 520 nm (Anonymous, 1973).

The control plots showed very small variation in the pH-values (Table 1). Fertilized plots appeared to have slightly higher pH-values, most consistently in the case of ammonium nitrate fertilization (correl. coefficient $r = 0.74^{++}$, $n = 20$, with very high significance). With urea addition, the correlation is low ($r = 0.28$, $n = 20$). Nitrogen fertilizers application would tend to decrease the C/N ratio, and a negative correlation between application doses and C/N ratio could be found with high significance level (correl. coefficient $r = -0.60^{++}$, $n = 20$, for urea plots and $r = -0.58^{++}$, $n = 20$, for ammonium nitrate plots).

RESULTS AND DISCUSSION

The data on the CO_2-release are presented in Fig. 1 expressed as percentage of total carbon after nine weeks' incubation and in Fig. 2 expressed as mg C/g dry weight per week during incubation time. In Fig. 1 one may observe some difference in the reaction to nitrogen fertilizers added in the field experiment. The treatment with ammonium nitrate showed no clear effect on the CO_2-release (a very low positive correlation, $r = 0.18$, $n = 10$, not significant). On the other hand urea may have decreased the CO_2-evolution from humus samples (a negative correlation with $r = -0.63$, $n = 8$, without N2PK-plots resp. $r = -0.61$, $n = 10$, with N2PK-plots, but still under significance level).

The contents of inorganic nitrogen after six and nine weeks' incubation indicates a positive influence of nitrogen fertilization on the nitrogen mineralization in humus from the experimental area. This is much clearer in the samples from plots fertilized with urea than in the samples from the plots treated with ammonium nitrate (compare Table 2 and Table 3). The analytical data show that the humus from the experimental area is not nitrifying under natural conditions (samples from control plots). Nitrification could be observed only after fertilization, as shown by the samples from plots with higher

doses of urea fertilizers (N2 and N3). But similar doses of ammonium nitrate fertilizers did not lead to nitrification in most of the samples investigated (only samples from plot No 56, N3, and No 58, N2, showed moderate or small amounts of nitrate after incubation).

There seems to be a relation between the occurrence of nitrification and the mineralization of nitrogen level. In the present material from this incubation experiment, all samples with more than 5 per cent of the nitrogen mineralized in nine weeks showed strong nitrification under this experimental condition whereas samples with less than 5 per cent nitrogen mineralized little or had no nitrification. Most of the humus samples of the same incubation experiment from plots fertilized with ammonium nitrate showed a percentage of mineralization rate lower than 5 % (compare Table 4).

The pH-values increased after incubation as a result of higher ammonium nitrogen content, but this increase was lower (depressed) in samples with high nitrate formation (Table 1).

The amounts of inorganic nitrogen calculated as kg N per hectare are presented in Fig. 3. The data for the control plots are low, which is in agreement with the positive growth response for nitrogen as indicated by tree growth measurements (Holmen, and al., 1976). The nitrogen fertilization can help to satisfy the actual requirement of the vegetation, but at the same time change the properties of soil humus. One part of the fertilized nitrogen is immobilised and incorporated in the soil humus, and this nitrogen seems to be more remineralisable than native soil nitrogen. It is not known just now, how long this effect might last.

Nitrate formation in acid forest soil after urea application has been found in the long-term lysimeter experiment (40 months) by Overrein

(1971, 1972) in Norway. Nitrate-nitrogen was found in the leachate already after a relatively moderate urea application (250 kg N/ha) with a total amount of leached nitrate-nitrogen corresponding to 14.9 kg N per hectare after 40 months. With higher doses of urea application the amount of leached nitrate-nitrogen increased up to 210 kg N/ha for the highest dose of urea-application (corresponding to 1 000 kg N/ha). In our case the urea-application corresponding to 260 kg N/ha showed no nitrate formation, but it must be pointed out that in contrast to Overrein's experiment here the fertilization was applied every spring for five years.

After the higher dose of urea (corresponding to 520 kg N per hectare) an amount of nitrate nitrogen up to 26.2 kg N/ha (see Fig. 3) was produced during nine weeks of incubation. The occurrence of nitrification in humus samples from plots with urea-fertilization in the field experiment Norrliden, is in good agreement with the results reported by Heilman (1974) especially about the effect of prior urea fertilization on nitrate production. Urea fertilization was shown to increase the capability of soils to nitrify subsequent urea-application. Although initial urea fertilization may not increase nitrate formation (for example if a low application rate is applied), periodic refertilization with urea may lead to substantially increased nitrate production.

Incubation experiments conducted with humus samples from different forest stands in Greece, after pretreatment with urea, showed no occurrence of nitrification in the humus samples, which were non-nitrifying before treatment (Nakos, 1976). The same author also investigated a series of nitrifying humus samples, and there he found a clear increase of nitrification after urea treatment.

Therefore it seems necessary to repeat incubation experiments of this type on samples from plots at varying periods after fertilizer applications to insure that excessive leaching will not be a consequence of repeated urea fertilization, or urea fertilization

followed relatively soon by clear-felling.

This influence of fertilizer nitrogen on the soil humus seems to be more pronounced after application of urea than of ammonium--nitrate. In the later case we have to expect a leaching of nitrate relatively soon after application of ammonium-nitrate, but apparently less biochemical changes in humus properties.

SUMMARY

Humus and mineral soil samples from an optimum nutrition experiment in young pine forest were taken into the laboratory for incubation tests on the effects of nitrogen fertilizers on the nitrogen mineralization, especially the occurrence of nitrification.

Very intensive nitrogen fertilizer application (ammonium nitrate and urea) seems to have changed some chemical properties of the soil humus (for example pH-reaction, C/N ratio etc.). The content of inorganic nitrogen increased after incubation in the samples from fertilized plots, particularly where the nitrogen had been added as urea.

Intensive nitrification occurred in the humus from plots treated with higher doses of urea; these samples also showed an intensive mineralization of nitrogen (about 5 % in nine weeks) expressed as a percentage of Kjeldahl-nitrogen.

Even very high application of ammonium-nitrate fertilizer did not result in nitrification (except of one of the plots with the highest application rate).

Less CO_2 was produced in samples from plots with high rates of urea application.

ACKNOWLEDGEMENT

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SAMMANFATTNING

För undersökning av gödslingseffekten på kvävemineralisering i skogsmark, speciellt av en eventuell nitratbildning efter intensiv kvävetillförsel i fältförsök, har utnyttjats ett s.k. näringsoptimeringsförsök i en ung tallplantering i Norrland. Som resultat av intensiv kvävegödsling (i form av ammoniumnitrat och urea) erhölls en förhöjd halt av oorganiskt kväve (ammonium och nitrat) i humusprover från gödslade ytor. Prover från ogödslade ytor visade knappast någon nettoproduktion av oorganiskt kväve under inkubationstiden.

Mycket intensiv kvävetillförsel har påverkat vissa av humuslagrets kemiska egenskaper, t.ex. pH, C/N kvot osv.

Trots att Norrlidens humus icke är nitrifierande i naturligt tillstånd, visade proven en stark nitratbildning efter högre urea-givor (520 kg N/ha och mera), men nästan ingen efter lika stora givor av ammoniumnitrat, utom i ett fall (en yta med N3 dos).

Nitrifikation i humus från urea-gödslade ytor uppträdde endast vid hög mineraliseringsprocent av kväve (över 5 % av Kjeldahl--kväve mobiliserat under nio veckor).

Gödslingen med ammoniumnitrat hade ingen klar effekt på CO_2-avgivningen från humusen under inkubationstiden, en svag positiv korrelation kunde spåras (r = 0.18, ej signifikant).

Urea-gödslingen minskade den respirerade CO_2-mängd under nio veckors inkubation, en negativ korrelation konstaterades men fortfarande under signifikansnivå (r = -0.63 resp. r = -0.61, n = 10).

Den konstaterade ökningen av halten oorganiskt kväve hos humusprover från gödslade parceller indicerar en snabbare mineralisering, dvs. en snabbare kväveomsättning, som kan vara en positiv förändring hos humus med mycket långsam omsättning i naturligt tillstånd.

Å andra sidan kan en intensiv nitrifikation efter gödsling med urea innebära vissa risker för nitratutlakning hos svenska skogsmarker, särskilt om en kalhuggning följer snart efter gödslingen.

REFERENCES

Anonymous, 1971. Interkalibrering av metoden för bestämning av nitrat och total nitrogen. - Nord.forsk.Miljövårds sekretariatet, publ. 3.

Heilman, P., 1974. Effect of Urea Fertilization on Nitrification in Forest Soils of the Pacific Northwest. - Soil Sci. Soc. of Amer. Proc. Vol. 38/4, 664-667.

Holmen, H., 1977. Skogsgödsling i Sverige 1976. - Kungl. Skogs- och Lantbruksakademiens Tidskr. No 6, 1977.

Holmen, H., Nilsson, Å., Popović, B., and Wiklander, G., 1976. The optimum nutrition experiment Norrliden. A brief description of an experiment in a young stand of Scots pine. - Skogshögskolan, Avd f skogsekologi, Rapporter och Uppsatser No 26. Stockholm.

Nakos, G., 1976. Interactions of nitrogen fertilizers and forest humus. - I. Fir and black pine. - Soil Biol. and Biochemistry, Vol. 8, 379-383.

Nömmik, H., 1971. A technique for determining mineralization of carbon in soils during incubation. - Soil Sci., Vol. 112/2, 131-136.

Overrein, L., 1971. Isotope Studies on Nitrogen in Forest Soil. I. Relative loss of nitrogen through leaching during a period of forthy months. - Medd. Norsk. Skogf. No 114, B XXIX, H. 5, 263-275.

Overrein, L., 1971. Isotope Studies on the leaching of different forms of nitrogen in forest soil. - Medd. Norsk. Skogf. No 106, B XXVIII, H. 6, 335-351.

Overrein, L., 1972. Isotope Studies on Nitrogen in Forest Soil. II. Distribution and recovery of ^{15}N-enriched fertilizer nitrogen in a 40 month lysimeter investigation. - Medd. Norsk.Skogf. No 122, B XXX, H. 4, 308-324.

Popović, B., 1971. Effect of sampling date on nitrogen mobilisation during incubation experiments. - Plant and Soil, Vol. 34, No 2, 381-392.

Roberge, M.R. and Knowles, R., 1966. Ureolyşis, Immobilisation and Nitrification in Black Spruce (*Picea Mariana Mill*) Humus. - Soil Sci. Soc. Amer. Proc., Vol. 30, 201-204.

Selmer-Olsen, A.R., 1971. Determination of ammonium in soil extract by an automated indophenol method. - Analyst. 16, 565-568.

Tamm, C.O. and Popović, B., 1974. Intensive fertilization with nitrogen as a stressing factor in a spruce ecosystem. I. Soil effects. - Studia Forestalia Suecica, No 121.

Weetman, G.T., Knowles, R. and Hills, 1972. Effects of different forms of nitrogen fertilizer on nutrient uptake by black spruce and its humus and humus mesofauna. - Woodlands Reports WR/39.

Table 1. Experiment E55 Norrliden. C/N ratio and pH-values in humus samples from different fertilized plots, dry weight of layer. Sampling September 1975.

Treat-ment	Experiment with urea				Experiment with ammonium-nitrate			
	pH (H_2O)		C/N	Dry weight	pH (H_2O)		C/N	Dry weight
	at start	after 9 weeks		10^{-3}kg/ha	at start	after 9 weeks		10^{-3}kg/ha
Control	4.2	4.3	39	32.2	4.3	-	38	42.9
"	4.2	-	38	36.1	4.1	4.4	42	40.2
"	4.1	4.4	54	45.8	4.4	4.4	42	42.9
P2K2	4.3	-	32	31.2	4.3	-	54	46.5
P2K2	4.1	-	43	36.6	4.2	-	38	29.7
Average	4.2		43	36.4	4.2		43	40.4
N1	4.6	5.0	32	29.7	4.2	-	33	28.5
N1	4.3	-	33	44.2	4.1	4.5	37	42.1
N1	4.4	4.9	34	37.4	4.4	4.4	31	37.5
N1P2K2	4.3	-	33	33.6	4.4	-	34	40.2
N1P2K2	4.4	-	37	39.2	4.3	-	32	24.8
Average	4.4		34	36.8	4.3		34	34.6
N2	4.5	-	25	44.4	4.7	-	33	40.0
N2	4.1	4.4	31	44.9	4.6	4.9	32	33.3
N2	4.9	4.7	26	26.5	4.3	4.5	34	47.1
N2P2K2	4.4	4.8	34	29.6	4.3	4.8	41	63.5
N2P2K2	4.5	4.2	31	43.8	4.5	4.8	34	35.5
Average	4.5		29	39.8	4.5		35	43.9
N3	4.2	4.6	28	31.8	4.7	-	33	36.7
N3	4.4	-	28	31.7	4.6	4.8	33	45.8
N3	4.5	4.5	34	38.2	4.4	4.6	31	35.3
N3P2K2	4.3	-	34	44.9	4.7	-	32	32.3
N3P2K2	4.2	-	34	37.1	4.8	-	36	39.6
Average	4.3		31	36.7	4.6		33	37.9

N1 = 260 kg N/ha (1971-75)
N2 = 520 kg N/ha (1971-75)
N3 = 780 kg N/ha (1971-75)
P2 = 80 kg P/ha (1971-75)
K2 = 152 kg K/ha (1971-75)

Table 2. Amount of inorganic nitrogen (NH_4-N + NO_3-N) in humus- and min. soil samples from differently fertilized plots after incubation test. Norrliden E55, sampling in September 1975. N µg/g d.w.

Treatment (in field)	Plots No	Ammonium-nitrate experiment Incubation time, weeks 0	6	9
Control	37	<1 (<1)+	10 (<1)	6 (<1)
"	50	6 (<1)	7 (<1)	31 (<1)
"	51	6 (<1)	7 (<1)	11 (<1)
P2K2	41	2 (<1)	8 (<1)	6 (<1)
P2K2	59	1 (<1)	54 (<1)	80 (<1)
N1	38	8 (<1)	11 (<1)	63 (<1)
N1	53	20 (<1)	108 (2)	185 (2)
N1	57	155 (<1)	132 (<1)	166 (<1)
N1P2K2	40	16 (<1)	69 (<1)	98 (<1)
N1P2K2	55	56 (<1)	46 (<1)	72 (<1)
N2	36	322 (<1)	90 (2)	391 (2)
N2	42	424 (2)	481 (4)	464 (4)
N2	52	104 (<1)	149 (<1)	205 (<1)
N2P2K2	43	150 (2)	200 (2)	240 (2)
N2P2K2	58	218 (4)	340 (28)	298 (21)
N3	39	353 (2)	340 (4)	380 (4)
N3	44	240 (4)	306 (7)	338 (7)
N3	56	371 (11)	461 (42)	546 (133)
N3P2K2	45	158 (1)	136 (6)	228 (10)
N3P2K2	54	264 (6)	379 (8)	392 (12)

+ nitrate nitrogen

Table 3. Amount of inorganic nitrogen (NH_4-N + NO_3N) in humus and mineral soil samples from differently fertilized plots after incubation test. Norrliden E55, sampling in September 1975. N µg/g d.w.

Treatment (in field)	Plots No	Urea experiment, Incubation time, weeks 0	6	9
Control	67	2 (<1)+	18 (<1)	41 (<1)
"	80	3 (<1)	28 (<1)	66 (<1)
"	83	1 (<1)	5 (<1)	10 (<1)
P2K2	66	7 (<1)	68 (<1)	76 (<1)
P2K2	87	1 (<1)	12 (<1)	34 (<1)
N1	68	276 (<1)	448 (<1)	552 (2)
N1	81	34 (<1)	214 (<1)	251 (<1)
N1	86	99 (<1)	264 (<1)	264 (<1)
N1P2K2	71	50 (<1)	320 (<1)	451 (<1)
N1P2K2	89	9 (<1)	132 (<1)	204 (2)
N2	73	793 (96)	1 263 (607)	1 277 (590)
N2	74	364 (98)	667 (292)	754 (376)
N2	82	722 (62)	1 174 (246)	1 239 (352)
N2P2K2	69	138 (14)	344 (95)	642 (317)
N2P2K2	88	150 (24)	445 (271)	530 (368)
N3	70	445 (111)	639 (215)	730 (226)
N3	72	780 (151)	1 040 (418)	1 059 (437)
N3	84	620 (95)	935 (260)	920 (264)
N3P2K2	75	402 (126)	664 (318)	720 (335)
N3P2K2	85	339 (98)	653 (264)	702 (288)

+ nitrate nitrogen

Table 4. Inorganic nitrogen as percentage of Kjeldahl-N after incubation in humus samples from differently fertilized plots. Experiment Norrliden E55. Sampling in September 1975.

Treatment (in field)	N-Kjeldahl % D.W.	Ammonium-nitrate experiment Incubation time, weeks 0		6		9	
Control	0.79	–	–	0.1	–	0.1	–
"	0.79	0.1	–	0.1	–	0.4	–
"	0.75	0.2	–	0.1	–	0.1	–
P2K2	0.72	–	–	0.1	–	0.1	–
P2K2	0.77	–	–	0.7	–	1.0	–
N1	0.89	0.1	–	0.1	–	0.7	–
N1	0.87	0.2	–	1.2	–	2.1	–
N1	1.02	1.5	–	1.3	–	1.6	–
N1P2K2	0.86	0.2	–	0.8	–	1.1	–
N1P2K2	1.13	0.4	–	0.4	–	0.6	–
N2	0.82	3.9	–	1.1	–	4.8	–
N2	1.09	3.9	–	3.9	–	4.3	–
N2	0.82	1.3	–	1.8	–	2.5	–
N2P2K2	0.65	2.3	–	3.1	–	3.7	–
N2P2K2	0.95	2.3	–	3.6	(0.3)+	3.1	(0.2)
N3	0.77	4.6	–	4.6	–	4.9	(0.1)
N3	0.72	3.3	(0.1)	4.2	(0.1)	4.7	(0.1)
N3	0.98	3.8	(0.1)	4.7	(0.4)	5.6	(1.4)
N3P2K2	0.75	2.1	–	1.8	(0.1)	3.0	(0.1)
N3P2K2	0.78	3.4	(0.1)	4.8	(0.1)	5.0	(0.1)

+ nitrate nitrogen

Table 5. Inorganic nitrogen as percentage of Kjeldahl-N after incubation in humus samples from differently fertilized plots. Experiment Norrliden E55. Sampling in September 1975.

Treatment (in field)	N-Kjeldahl % D.W.	Urea experiment Incubation time, weeks 0		6		9	
Control	0.85	-	-	0.2	-	0.5	-
"	0.84	-	-	0.3	-	0.8	-
"	0.63	-	-	0.1	-	0.2	-
P2K2	0.86	0.1	-	0.8	-	0.9	-
P2K2	0.84	-	-	0.1	-	0.4	-
N1	1.24	2.2	-	3.6	-	4.5	-
N1	0.90	0.4	-	2.4	-	2.8	-
N1	1.04	1.0	-	2.5	-	2.5	-
N1P2K2	1.25	0.4	-	2.5	-	3.6	-
N1P2K2	0.86	0.1	-	1.6	-	2.4	-
N2	1.24	6.4	(0.8)+	10.2	(4.9)	10.3	(4.8)
N2	0.81	4.5	(1.2)	8.2	(3.6)	9.3	(4.6)
N2	1.29	5.6	(0.5)	9.1	(1.9)	9.5	(2.7)
N2P2K2	1.13	1.2	(0.1)	3.0	(0.8)	5.7	(2.8)
N2P2K2	0.98	1.5	(0.2)	4.6	(2.8)	5.4	(3.8)
N3	0.88	5.0	(1.2)	7.3	(2.4)	8.3	(2.5)
N3	1.03	7.5	(1.5)	10.1	(4.1)	10.3	(4.2)
N3	1.06	5.8	(0.9)	8.3	(2.4)	8.7	(2.5)
N3P2K2	1.00	4.0	(1.3)	6.6	(3.2)	7.2	(3.3)
N3P2K2	1.02	3.3	(1.0)	6.6	(2.6)	6.9	(2.8)

+ nitrate nitrogen

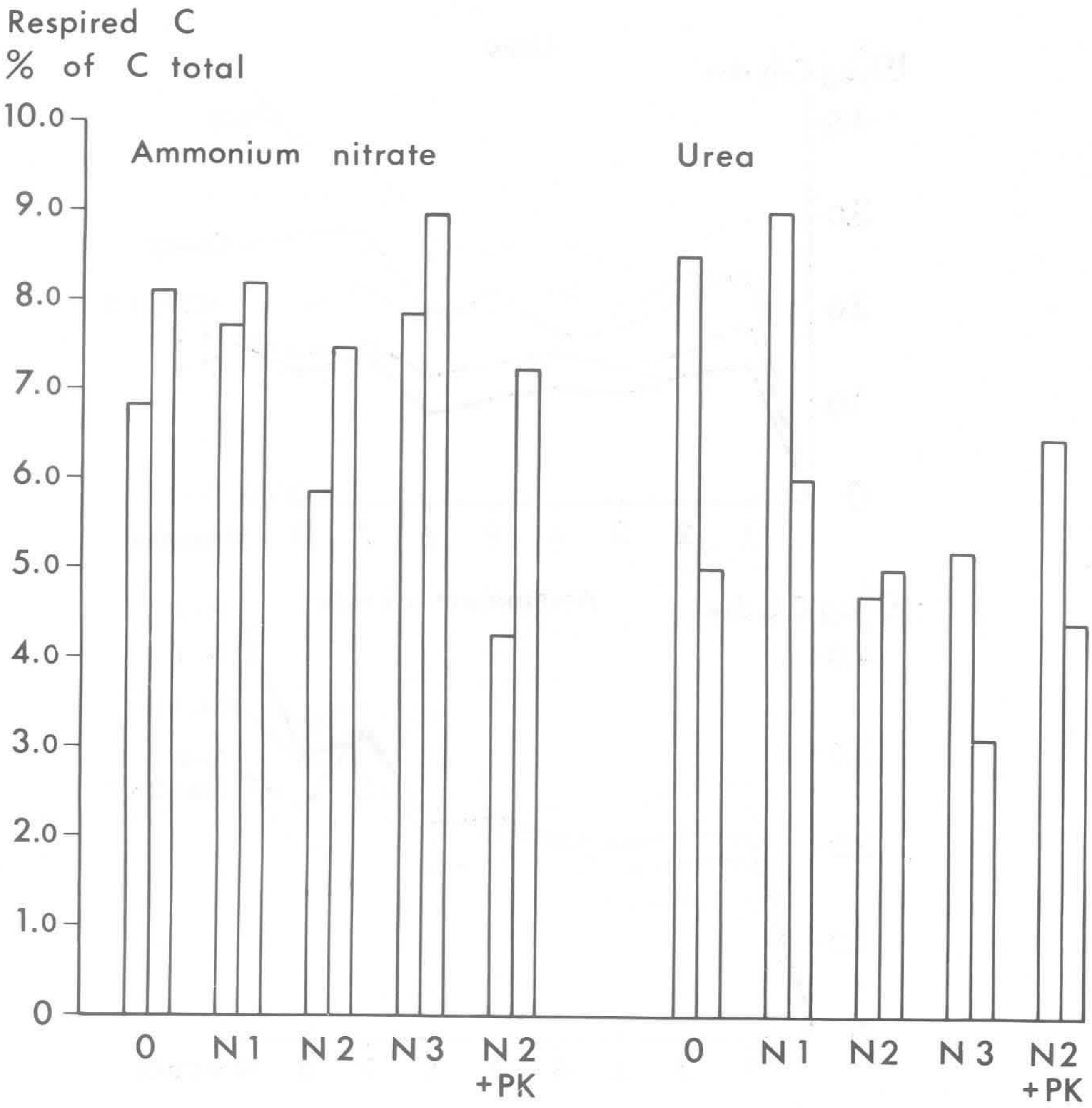


Fig. 1. Total amount of CO_2 (C % of C total initially) respired during nine weeks' incubation. Experimental area Norrliden E55. Sampling September 1975. Mean values of four replications.

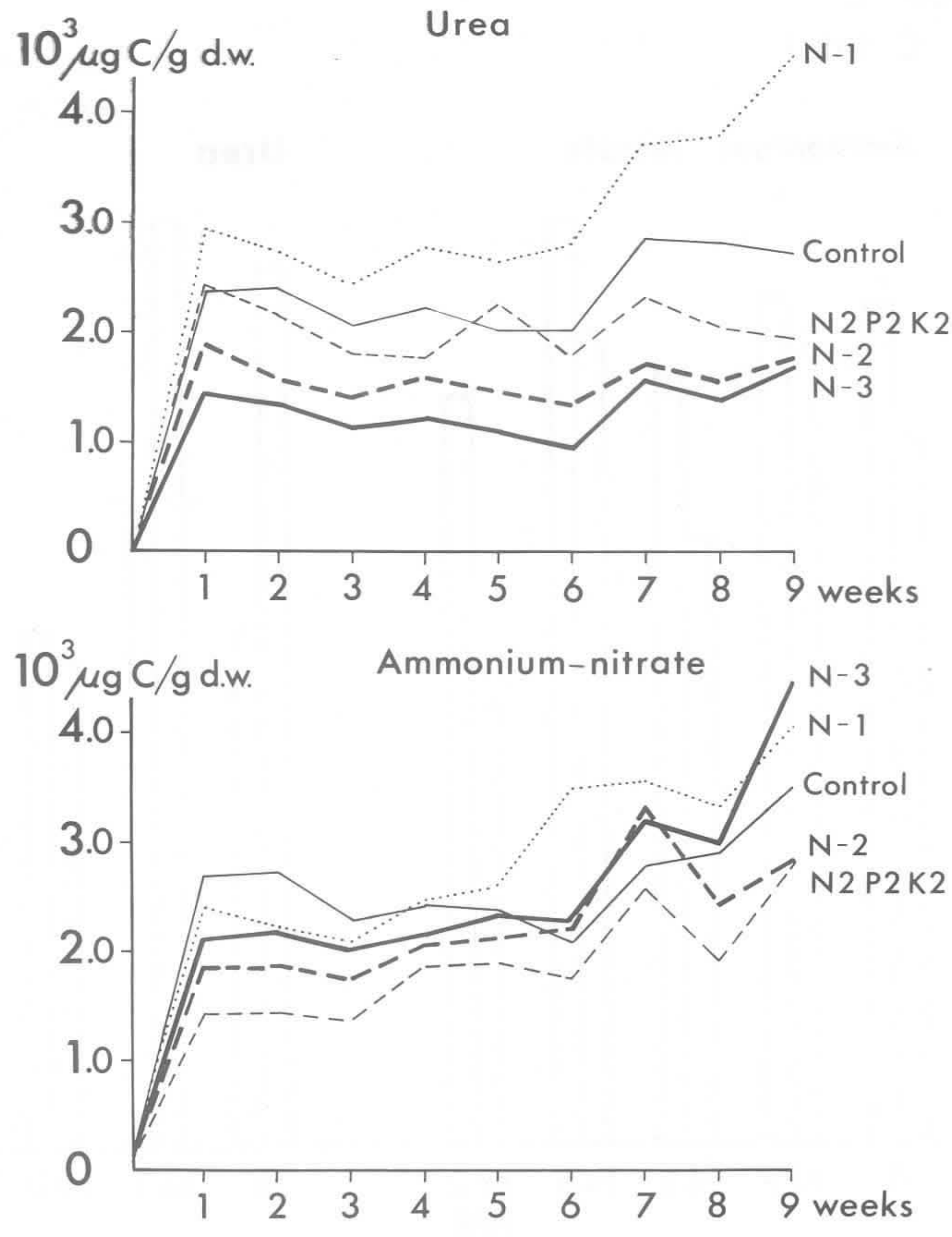


Fig. 2. Respired quantity of CO_2 in µg C/g initial dry weight per week during incubation of humus samples from different fertilized plots. Experiment Norrliden E55.

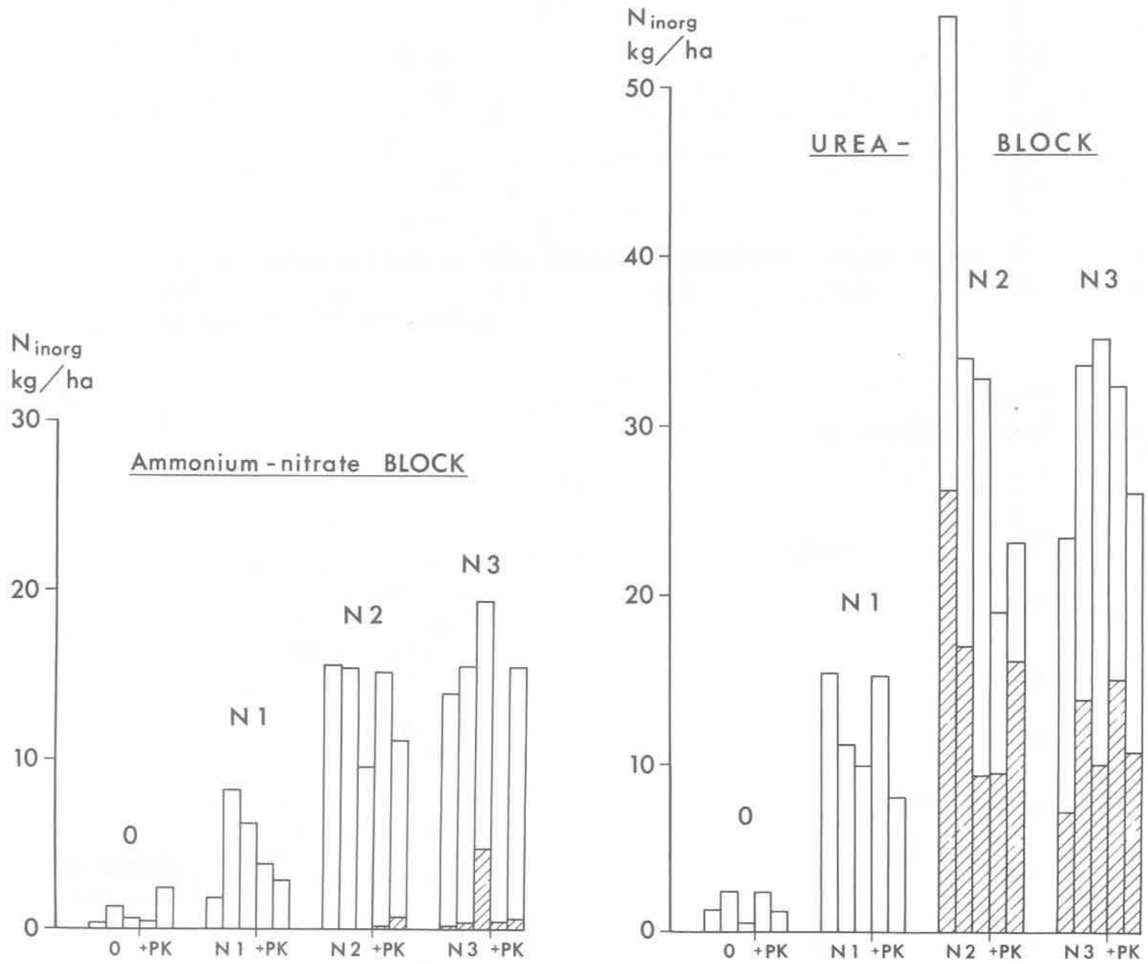
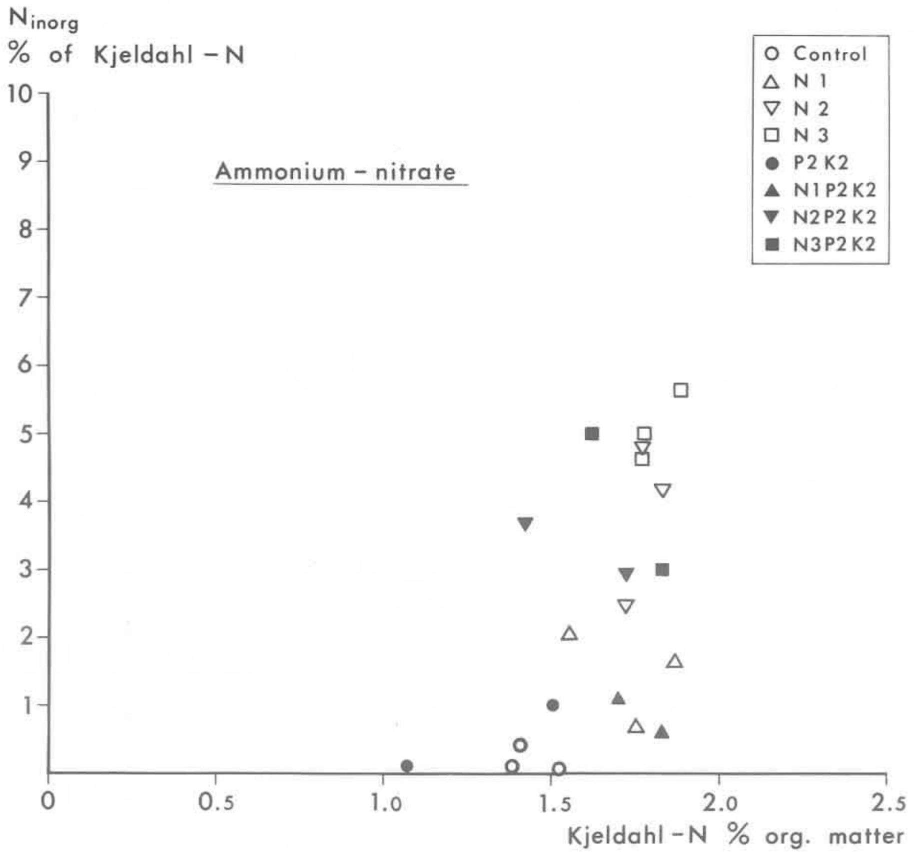


Fig. 3. Total amount of inorganic nitrogen (kg N/ha) after nine weeks' incubation in humus layer from differently fertilized plots. Mean values of four replications. Hatched bars = nitrate nitrogen.



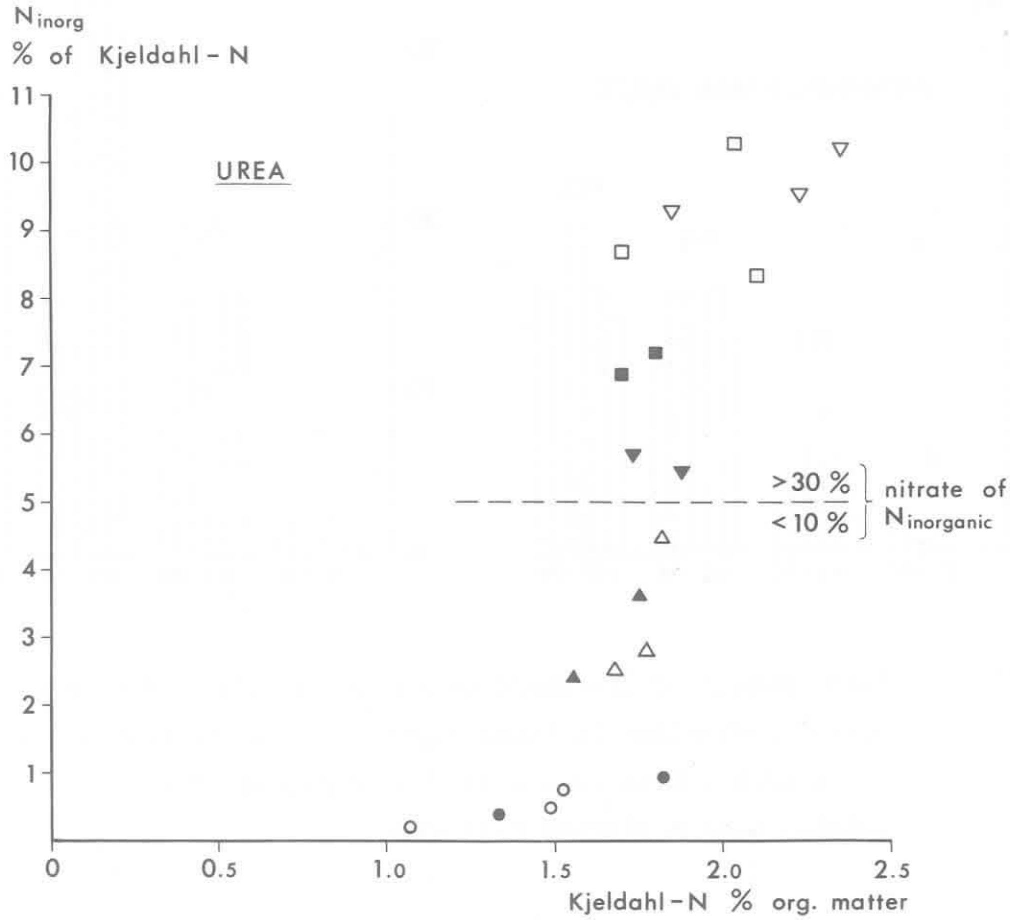


Fig. 4 and 5. Inorganic nitrogen as percentage of Kjeldahl-N after nine weeks' incubation in humus samples from differently fertilized plots. Experimental area Norrliden E55.